Influence of Water Depth, Coverage and Aeration on the Treatment Efficiency of Experimental Constructed Floating Wetlands

Annelies M.K. Van de Moortel[a], Niels De Pauw[b], Filip M.G. Tack[a]

[a]Laboratory of Analytical Chemistry and Applied Ecochemistry, Ghent University, Coupure Links 653, 9000 Ghent, Belgium
[b]Laboratory of Environmental Toxicology and Aquatic Ecology, Ghent University, J. Plateaustraat 22, 9000 Ghent, Belgium

INTRODUCTION

Constructed floating wetlands (CFWs) form the link between pond systems and conventional substrate-based systems. The use of emergent plants is in common with constructed wetland systems and the presence of a free-water compartment with pond systems.

METHODS

Three mesocosms simulating full scale retention basins (length: 1.5m; width: 0.8m; water depth: 0.9m) were constructed in January 2007. Two of them were equipped with floating macrophyte mats planted with *Carex* spp. The systems were batch loaded with domestic waste water. Aeration was provided by air diffusers at the bottom of one of the two CFWs at a rate of 3.1 L air min^{-1} m^{-3} water during a first experiment (retention time 11 days). During a second experimental period, water depth was altered in one CFW (45cm, 60cm, 90cm and 115cm; retention time 11 days). Finally, half of one of the floating mats was removed in order to evaluate the effect of plant coverage (retention time 9 days). The removal of total nitrogen (TN), ammonium-nitrogen (NH_4-N), total phosphorus (TP) and carbon (TOC, COD) was evaluated by analysing water samples.

RESULTS and DISCUSSION

Aeration resulted in a significant improvement of the removal of TN, NH_4-N, TP, TOC and COD (Table 1). All NH_4-N was removed within 4 days of aeration. Furthermore, most removal occurred within the first 4 days in the aerated system whereas a gradual decrease was observed in the nonaerated wetland and control throughout the 11 days. No significant difference for the aerated system was observed after 4 or 11 days. NO_3-N concentrations in the aerated wetland increased up to 5 mg L^{-1} whereas concentrations remained low (< 0.5 mg L^{-1}) in the nonaerated wetland and control. Denitrification in the aerated wetland was hampered as dissolved oxygen concentrations increased to more than 10 mg L^{-1}. Furthermore, organic carbon present after 4 days of aeration did not change and varied between 10 and 12 mg L^{-1}, indicating that the remaining fraction was recalcitrant and not readily degradable by the denitrifiers.

The 100% coverage of the water surface with a floating macrophyte mat resulted in significantly better removal of NH_4-N and TP (Table 2). For TN no significant effect of coverage was observed. Previous researchers stated that partial coverage of the water surface would promote removal reactions as oxygen diffusion from the air to the water column is less hampered. However, it seems that plant uptake and plant oxygen release can compensate for this enhanced oxygen diffusion effect. The obtained test results suggest that 100% coverage results in the best removal performance.

Table 1 Average removal efficiencies (%) after 4 and 11 days for the two CFWs with and without aeration, and the control

After 4 days	CFW + aeration (%)	CFW – aeration (%)	Control (%)
NH_4-N	>99	27.4 ± 11.3	-8.6 ± 9.9
TN	60.6 ± 8.6	25.5 ± 9.6	9.4 ± 5.3
NO_3-N		38.8 ± 68.3	79.0 ± 22.1
TP	50.6 ± 11.0	20.7 ± 25.3	-1.8 ± 15.0
TOC	64.1 ± 12.4	18.5 ± 3.6	6.5 ± 8.5
COD	66.8 ± 2.4	37.4 ± 17.7	18.1 ± 2.1
After 12 days	**CFW + aeration (%)**	**CFW – aeration (%)**	**Control (%)**
NH_4-N	>99	43.2 ± 10.9	2.3 ± 15.1
TN	67.9 ± 5.7	43.0 ± 8.1	3.7 ± 15.2
NO_3-N		24.3 ± 25.3	84.5 ± 5.2
TP	59.4 ± 2.9	35.1 ± 11.7	-0.5 ± 9.5
TOC	69.0 ± 5.3	22.6 ± 18.5	9.1 ± 10.4
COD	68.7 ± 5.0	55.2 ± 4.4	29.4 ± 22.1

Table 2 Average removal efficiencies for the various percentages of coverage

Coverage (%)	TOC (%)	NH_4-N (%)	TN (%)	TP (%)
0	15.1 ± 13.2	-1.4 ± 4.6	0.9 ± 5.0	-5.0 ± 14.3
50	18.8 ± 12.9	-2.2 ± 6.7	0.8 ± 8.2	-10.2 ± 2.0
100	12.8 ± 15.7	7.5 ± 11.4	1.4 ± 25.5	6.8 ± 19.0

The removal performances obtained during the test with varying water depths is presented in Table 3. Water depth influenced significantly the removal with the highest removal of NH_4-N, TN and TP at a water depth of 45cm (Figure 3). The depth of the free water column is rather limited when dealing with such small depths as the floating mat was partly submerged. Its overall thickness was 12 to 15cm. At smaller water depths the relative contribution of the vegetation will increase as the water is in better contact with the vegetation, roots and attached biofilm.

Table 3 Average removal efficiencies for the CFWs with various water depths and the control

	Depth (cm)	NH_4-N (%)	TN (%)	TP (%)	TOC (%)
Control	90	6.7 ± 14.6	0.1 ± 11.9	19.4 ± 12.0	10.4 ± 15.3
CFWs	45	20.3 ± 4.0	24.6 ± 14.1	24.7 ± 22.6	16.7 ± 5.1
CFWs	60	6.7 ± 4.2	0.7 ± 8.1	7.7 ± 2.0	19.2 ± 20.2
CFWs	90	3.0 ± 15.1	2.4 ± 17.2	7.9 ± 18.1	23.9 ± 21.8
CFWs	115	-8.3 ± 6.4	3.9 ± 0.9	3.4 ± 10.6	11.1 ± 11.0

CONCLUSIONS

The addition of aeration resulted in increased removal performance in the CFWs. Furthermore, a 100% coverage is preferred as plant presence can compensate for enhanced oxygen diffusion at lower coverage rates. Using smaller water depths enhances the removal as a better contact is obtained between the vegetation and the wastewater.